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CHARACTERIZING THE DISTRIBUTION OF ESA LISTED SALMONIDS IN THE NORTHWEST TRAINING AND TESTING AREA WITH ACOUSTIC AND POP-UP SATELLITE TAGS

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14. ABSTRACT
This project supports Pacific salmonid studies in the offshore waters of the existing Northwest Training Range Complex (NWTRC) and offshore Naval Undersea Warfare Center Keyport Range Complex (together known as the Northwest Training and Testing (NWTT) Study Area). The goal of this study is to use a combination of acoustic and pop-up satellite tagging technology to provide critical information on spatial and temporal distribution of salmonids to inform salmon management, U.S. Navy training activities, and Southern Resident Killer Whale conservation. This report provides a progress update on this new study that includes four tasks: (1) the purchase and programming of tags; (2) determination of occurrence and timing of salmonids within the Navy training ranges; (3) a description of the influence of environmental covariates on salmonid occurrence, as well as (4) in relation to Southern Resident Killer Whale distribution. During the current reporting period, pop-up satellite tags were obtained and field work is planned for 2019. Information on a pilot study conducted during June 2018 is included.

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Background:

The U.S. Navy conducts military training and testing in Pacific Northwest range areas to prepare combat-ready military forces, whereas NOAA Fisheries is responsible for managing threatened and endangered species in marine waters and providing permits to the U.S. Navy. NOAA Fisheries and the U.S. Navy share the common goals of minimizing the impact of military training and testing activities on endangered species without compromising training and testing efforts and reducing adverse environmental effects. This work provides vital geographic and distributional data within the Navy's range areas, allowing the Navy the flexibility to proceed with training and testing while providing protective measures for both salmonids and killer whales.

This project specifically supports Pacific salmonid studies in the offshore waters of the existing Northwest Training Range Complex (NWTRC) and offshore Naval Undersea Warfare Center Keyport Range Complex (together known as the Northwest Training and Testing (NWTT) Study Area). In particular, this project addresses a region critical to Navy monitoring objectives and species of interest under current and future monitoring plans.

Characterizing the distribution and behavior of fish in nearshore marine environments is time-consuming and expensive. For species listed under the ESA, conservation of critical habitats requires detailed information on both temporal and spatial patterns of habitat use and, ideally, the relative importance of migration corridors, aggregation and foraging areas. Understanding where, when, and why these animals occupy specific habitats (e.g., depth, distance from shore, bottom type, temperature, DO, current, etc.) is necessary to improve the effectiveness of marine spatial planning, fisheries management, and restoration and recovery of listed species. The goal of this study is to use a combination of acoustic and pop-up satellite tagging technology to provide critical information on spatial and temporal distribution of salmonids to inform salmon management, U.S. Navy training activities, and Southern Resident Killer Whale (SRKW) conservation.

In this study we will examine the behavior and distribution of four species of salmonids (Chinook salmon, coho salmon, steelhead, and bull trout) in the northeast Pacific Ocean along the coast of Washington State by tagging individual fish with acoustic or pop-up satellite tags. Identification and recovery of salmon populations in the SRKW diet are important to effectively promote SRKW recovery since there is evidence that they have become prey limited due to reductions of their dominant prey, Chinook salmon (*Oncorhynchus tshawytscha*) (Ayers et al. 2012, NMFS 2008). Low prey abundance has been cited as an important factor limiting the recovery of the fish-eating SRKW. Chinook salmon have been shown to dominate SRKW diet early in the summer, with coho salmon increasingly contributing to more of the SRKW diet in late summer (Ford et al. 2016). The spatial and temporal overlap of SRKW and salmon also affects the distribution and effort expended by foraging SRKW.

Chinook salmon: The Lower Columbia River, Puget Sound, Snake River Fall-run, and Snake River Spring/Summer-run evolutionary significant units (ESU) of Chinook salmon are listed as threatened and the Upper Columbia River Spring-run ESU is listed as endangered under the ESA in Washington State. Chinook salmon are anadromous and semelparous. All of these ESUs use the nearshore coastal environment. Fishery independent data that delineates the distribution of individual salmonids within the Pacific Ocean is lacking. Importantly, we know little about the occurrence and movements of threatened salmonid populations, which often leave the shallow coastal environments, where most scientific sampling occurs, after entering the ocean (Teel et al. 2015). The coastal marine environment is an important habitat for Pacific salmonids. Conditions in this portion of the ocean are highly influential for salmonid growth, survival, and population dynamics (Peterson et al. 2014). The ability to detect tagged fish expand the spatial and temporal extent over which we can assess the distribution and behavior of Chinook salmon across the continental shelf in the coastal Pacific Ocean.

Coho salmon: The Puget Sound/Strait of Georgia ESU of coho salmon is listed as a species of concern and the Lower Columbia River ESU of coho salmon is listed as federally threatened in Washington State. Coho salmon and Chinook salmon are relatively closely related species, have similar life histories, and their diets overlap broadly. We have similar gaps in information about the distribution and behavior of Coho salmon in the marine environment as we do about Chinook salmon.

Steelhead: There are five distinct population segments (DPS) of steelhead that are listed as federally threatened in Washington State (Lower Columbia River, Middle Columbia River, Puget Sound, Snake River Basin, and Upper Columbia River). Steelhead are the anadromous form of rainbow trout and are iteroparous. Steelhead tend to migrate through estuaries and leave coastal waters soon after entering the ocean (Miller et al. 1983). Steelhead are less abundant than semelparous salmon and may return to freshwater to spawn year-round which makes understanding their marine distributions more difficult (Quinn 2005). There is some evidence that steelhead from coastal rivers (Hayes et al. 2011) may travel farther distances in marine waters than steelhead in large river and estuary systems (Teo et al. 2013)

Bull trout: The Columbia River (DPS) and Puget Sound/Coastal DPS of bull trout are listed as federally threatened. Bull trout are facultatively anadromous species and iteroparous. There is evidence from radio telemetry and otolith microchemistry that bull trout spend time in marine waters and transit between coastal rivers along the coast of Washington State (Brenkman et al. 2007). However, only limited information exists for the spatial distribution of bull trout in marine waters.

This study will provide data on the spatial extent and timing of the use of coastal marine waters by Chinook salmon, coho salmon, steelhead and bull trout. Salmonids are of particular interest to killer whale managers because they are important prey for this endangered species (Williams et al. 2011, Hilborn et al. 2012, Killer Whale 5-year Action Plan). Similarly, there is evidence that salmonid abundance affects killer whale survival (Ford et al. 2010) and fitness (Ward et al. 2009, Ruggerone et al. 2019). The overlap of resident killer whales and salmonids in space and time affects the distribution and effort expended by foraging killer whales, and the resulting impact on salmonid survival. A better understanding of the distribution of salmon in the ocean would improve U. S. National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries) decisions for both salmonids and killer whales.

Summary of Tasks:

1. Purchase and program tags
2. Capture, tag, and release salmonids
3. Determine the occurrence and timing of salmonids within the Navy training ranges
4. Describe the influence of environmental covariates on salmonid occurrence
5. Describe the occurrence of salmonids in relation to Southern Resident Killer Whale distribution

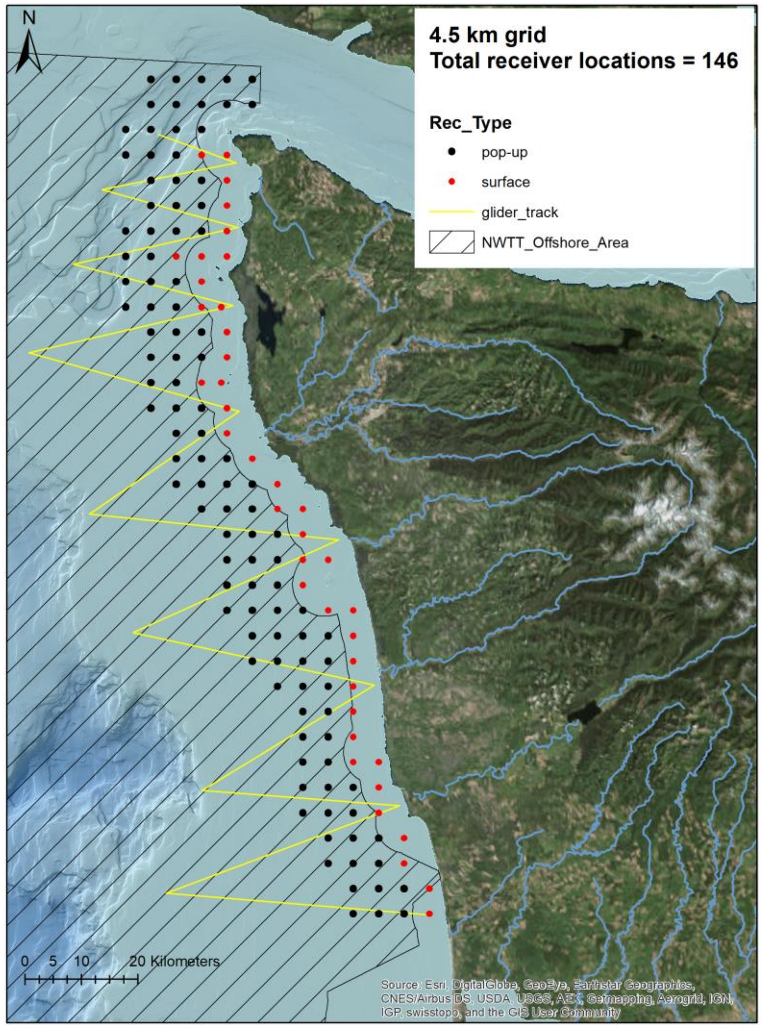

Figure 1. Study area indicating the location of pop- up stationary receivers (black circles) and surface retrieval stationary receivers (red circles) and potential glider path (yellow line). Purple area indicates receivers within the NWTT and light blue indicates receivers outside the NWTT.

Progress on Task 1 - Purchasing and programming tags:

The NOAA purchase request for acoustic telemetry equipment was submitted on October 1st 2018. Currently the purchase is undergoing a technical panel review within NOAA. We expect to receive equipment by March 2019. Pop-up satellite tags have been obtained are ready for deployment. An ARGOS satellite account has been setup and is ready for tag deployments. Relevant permit applications (WDFW, Section 10, Aqui-S, INAD study) have been submitted and are scheduled to be received before tagging occurs.

Progress on Task 2 – Capture, tag, and release salmonids:

The field work for this study is scheduled to start in 2019. We plan to focus on ESA listed species that include Chinook salmon, coho salmon, steelhead, and bull trout. Fish will be tagged with acoustic tags and pop-up satellite tags.

We conducted a pilot study to test fish capture and tag implanting at sea. We captured and tagged salmon for 5 days in June 2018 from a small NOAA vessel between the Columbia River mouth and Grey's Harbor, WA. We also captured and tagged salmon from a contract vessel, the Zephyr, for 2 days in August 2018. We deployed archival tags that were previous purchased and unused from another project. Our objective was to demonstrate success capturing and tagging salmon, and to work through logistical and technical considerations prior to our planned tagging season in May 2019. We easily captured 45 salmon that were appropriate for tagging at various depths along the coastal shelf of Washington in the vicinity of the study area (Figure 2). We deployed hooks for 12.8 hours across all of the sampling days (3.5 fish per hour). We anticipate greatly improving our catch rate for future sampling based on our pilot study experience. Our results indicated a high likelihood of success capturing and tagging fish for this project.

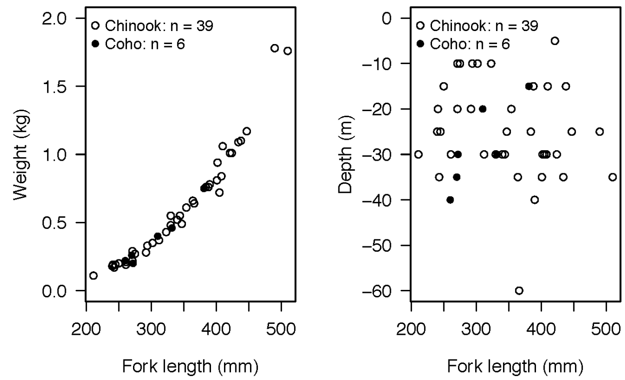

Figure 2. Salmon weights, lengths, and depths of capture from a pilot study conducted during summer of 2018 that demonstrated the feasibility of capturing and tagging salmon at sea using available small platforms.

Progress on Tasks 3-5:

The subsequent tasks require the collection of data from tagged fish. We expect progress towards completing these tags in the fall of 2019.

Methods planned for 2019:

Task 2 – Capture, tag, and release salmonids

We will tag a total of 100 individual fish with a combination of 69 kHz VEMCO V7-2L (n = 5), V7-4L (n = 5), V8-4L (n = 5), V9-6L (n = 20), V9-1L (n = 20), and V9-2L (n = 45) acoustic tags that will include three species (Chinook salmon = 40, coho salmon = 40, bull trout = 20). The expected detection range of tags will be between 200 m and 500 m and have an expected battery life of 172 to 651 days, depending on the battery size and power output (V7 = 136 dB, V8 = 144 dB, V9 = 145 dB) of the tag. We have purchased three reference tags that ping every 10 minutes for each of three power output levels (total of 9 reference tags). The three tags for each power output will be placed at three different distances from a receiver to determine empirical detection ranges for this study. Using pop-up satellite tags we will tag 10 individuals (Chinook = 4, steelhead = 4, bull trout = 2). For steelhead, we will capture and tag female kelts from 1-3 coastal rivers or reconditioning ponds, depending on the availability of fish. Female steelhead kelts are more likely to return than males (Wertheimer and Evans 2005). We will coordinate with an expert in the field to determine the best source for obtaining steelhead that will maximize the likelihood of providing quality data. The actual number of each species tagged may change based on catch availability. Chinook salmon, coho salmon, and bull trout will be captured using hook and line sampling in the northwest nearshore ocean and coastal rivers. Pop-up satellite tags will be programmed to release from the fish and download via satellite 3 months after tagging. We will also attempt to recover these tags at sea, if possible. These tags will record temperature, light, and depth information. We will use these data to characterize the environmental conditions that fish experience while in the ocean, which will improve our distribution models. We will tag Chinook salmon and coho salmon in the spring and early summer; we will tag steelhead in the winter; we will tag bull trout in winter, spring, and summer. We will collect a fin clip from each fish to determine the genetic stock of the individual. We will use a 4.5 km equally spaced grid pattern to assign locations of stationary receivers (Figure 1; Kraus et al. 2018). The extent of the receiver grid was bounded to be no farther than 10 nautical miles from shore and no closer than 1 nautical mile to shore. VEMCO receivers are able to detect the location of fish with VEMCO 69 kHz tags. This includes salmon and other species tagged by other researchers such as rock fish, tunas, green sturgeon, and white sharks.

Task 3 – Determine the occurrence and timing of salmonids within the Navy training ranges.

We scheduled the NOAA white ship 'Oscar Dyson' for 11th-19th of March 2019. We plan to deploy 101 of the pop-up (black circles) acoustic receivers as depicted in Figure 1. We currently have 42 acoustic receivers from other projects and we have purchased 100 more receivers. These data will allow us to determine when and where salmonids are present within the Navy training ranges. We will be able to determine the spatial extent that tagged fish occupy. Combining known ocean conditions and the information from pop-up satellite tags and acoustic tags detected by the stationary acoustic receiver array and AUV will allow us to estimate a trajectory of the route the fish traversed as well as the rate of movement. We will calculate the following metrics: 1) Residence time (per fish per receiver): The amount of time that a fish is within the range of the receiver. This is calculated as the sum of time between detections. A resident event ends once a fish has not been detected for more than an hour or if the fish is detected at another receiver. 2) Number of movements (per fish per receiver): The number of times that a fish visits a receiver. 3) Number of unique individuals (per receiver); the number of individual fish that are detected at a receiver. 4) Direction of movement (per fish per receiver): the compass direction from the current receiver to the previous receiver the fish was detected at. 5) Time of movement (per fish): the 24 h time at which a fish is detected for the first time at a receiver. 6) Movement speed (per fish): meters per second of movement between receivers. 7) Date of last detection (per fish): this is the last date the fish was detected.

We are working with Oregon State University researchers to deploy an autonomous underwater vehicle (Slocum Glider) that is integrated with two VEMCO acoustic receivers to detect acoustically tagged salmon. The advantage of integrating the receiver into the glider (i.e., wiring it into the system rather than simply attaching the receiver and recording transmissions) is that data is transmitted to the glider operators each time the AUV surfaces (e.g., location, time, VEMCO transmitter ID, etc.). Thus, fish detections and other data will be transmitted in real time, allowing for manual override of controls and real-time data reporting. Habitat data collected by the glider includes depth profiles of temperature, dissolved oxygen, salinity, turbidity, current, and chlorophyll. The survey will begin at the Cape Flattery, WA and fly in a zigzag pattern from near shore out to the 200 m isobath moving to the southern end of the Olympic Coast National Marine Sanctuary near Copalis Beach, WA. The glider will be programmed to operate between the 20 m and 200 m depth contours spanning the majority of the coastal shelf (Figure 1). The AUV will be deployed in June of 2019. The AUV can travel about 12 km per day and can operate about 26 days per deployment for a distance of about 300 km. We plan on two deployments that will cover a distance of about 600 km.

Task 4 – Describe the influence of environmental covariates on salmonid occurrence.

We will use oceanographic models to determine spatially explicit environmental conditions within the ocean. Coupling this information with temporally explicit detection data we can determine the relationship between salmonid distributions and specific habitat attributes. Using this information, we will estimate the travel route, residence time and rate of movement for each tagged fish. Eventually this information will be used to build a species distribution model that determines suitable habitat for each species.

Task 5 – Describe the occurrence of salmonids in relation to Southern Resident Killer Whale distribution.

We will coordinate and devise a specific analysis plan with Brad Hanson (NOAA, Northwest Fisheries Science Center) to examine the degree to which tagged salmonids and piscivorous ("resident" ecotype) killer whales overlap through space and time. Salmonids make up the dominant component of resident killer whale diets (Hanson et al. 2010). However, there is very little information about salmonid distribution in the ocean, especially in the winter. Data from this study will provide key insights into the role of salmonids as a prey source for killer whales and how fish occurrence and movements may influence whale occurrence patterns. The distribution of salmon prey that are large enough to be killer whale forage is seasonally dynamic among species and among populations within species. This work will fill this data gap by elucidating the behavior and spatiotemporal distribution of salmonids in the ocean. Additionally, this study will give the Navy information regarding areas of spatial overlap of killer whales and salmonids within the NWTT.

References:

Ayres, K. L., R. K. Booth, J. A. Hempelmann, K. L. Koski, C. K. Emmons, R. W. Baird, K. Balcomb-Bartok, M. B. Hanson, M. J. Ford, and S. K. Wasser. 2012. Distinguishing the Impacts of Inadequate Prey and Vessel Traffic on an Endangered Killer Whale (Orcinus orca) Population. Plos One 7: e36842.

Brenkman, S. J., S. C. Corbett, and E. C. Volk. 2007. Use of Otolith Chemistry and Radiotelemetry to Determine Age-Specific Migratory Patterns of Anadromous Bull

Trout in the Hoh River, Washington. Transactions of the American Fisheries Society 136(1):1–11.

Ford, J. K. B., G. M. Ellis, P. F. Olesiuk, and K. C. Balcomb. 2010. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? Biology Letters 6:139– 142.

Ford, M. J., J. Hempelmann, M. B. Hanson, K. L. Ayres, R. W. Baird, C. K. Emmons, J. I. Lundin, G. S. Schorr, S. K. Wasser, and L. K. Park. 2016. Estimation of a Killer Whale (Orcinus orca) Population's Diet Using Sequencing Analysis of DNA from Feces. Plos One 11:1-14.

Hanson, M. B., et al. 2010. Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. Endangered Species Research 11:69-82.

Hayes, S. A., M. H. Bond, B. K. Wells, C. V Hanson, A. W. Jones, and R. B. MacFarlane. 2011. Using Archival Tags to Infer Habitat Use of Central California Steelhead and Coho Salmon. American Fisheries Society Symposium 76:1–22.

Hilborn et al. 2012. The effects of Salmon Fisheries on Southern Resident Killer Whales: Final Report of the Independent Science Panel. Prepared with the assistance of D.R. Marmorek and A.W. Hall, ESSA Technologies LTD., Vancouver, B.C. for National marine Fisheries Service (Seattle, WA) and Fisheries and Oceans Canada (Vancouver, BC).

Killer whale 5-year Action Plan. Species in the Spotlight. Priority Actions: 2016-2020 Southern Resident Killer Whale DPS.

Kraus, R. T., C. M. Holbrook, C. S. Vandergoot, T. R. Stewart, M. D. Faust, D. A. Watkinson, C. Charles, M. Pegg, E. C. Enders, and C. C. Krueger. 2018. Evaluation of acoustic telemetry grids for determining aquatic animal movement and survival. Methods in Ecology and Evolution 9:1489-1502.

NMFS. Recovery Plan for Endangered Southern Resident Killer Whales (Orcinus orca): National Marine Fisheries Service, Northwest Region; 2008. Available: http://www.nwr.noaa.gov/Marine- Mammals/Whales-Dolphins-Porpoise/Killer-Whales/ESA-Status/Orca-Recovery-Plan.cfm.

Peterson, W.T., J.L. Fisher, J.O. Peterson, C.A. Morgan, B.J. Burke, and K.L. Fresh. 2014. Applied fisheries oceanography: Ecosystem indicators of ocean conditions inform fisheries management in the California Current. Oceanography 27(4):80–89.

Ruggerone, G. T., A. M. Springer, L. D. Shaul, and G. B. Van Vliet. 2019. Unprecedented biennial pattern of birth and mortality in an endangered apex predator, the southern resident killer whale, in the eastern North Pacific Ocean. Marine Ecology Progress Series 608(1):291–296.

Teel, D. J., B. J. Burke, D. R. Kuligowski, C. A. Morgan, and D. M. Van Doornik. 2015. Genetic identification of chinook salmon: Stock-specific distributions of juveniles along the Washington and oregon coasts. Marine and Coastal Fisheries 7:274–300.

Teo, S. L. H., P. T. Sandstrom, E. D. Chapman, R. E. Null, K. Brown, A. P. Klimley, and B. A. Block. 2013. Archival and acoustic tags reveal the post-spawning migrations, diving behavior, and thermal habitat of hatchery-origin Sacramento River steelhead kelts (*Oncorhynchus mykiss*). Environmental Biology of Fishes 96:175–187. Springer

Netherlands.

Ward, E. J., E. E. Holmes, and K. C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology 46:632–640.

Wertheimer, R. H., and A. F. Evans. 2005. Downstream passage of steelhead kelts through hydroelectric dams on the lower Snake and Columbia rivers. Transactions of the American Fisheries Society 134:853-865.

Williams, R., and coauthors. 2011. Competing conservation objectives for predators and prey: estimating killer whale prey requirements for Chinook salmon. PLoS ONE 6:e26738.